ACQUIRING WINGS

ACQUIRING WINGS

A TEXT ON THE BASIC PRINCIPLES GOVERNING THE DESIGN AND OPERATION OF MODERN AIR CRAFT

BY

WILLIAM B. STOUT

NEW YORK
MOFFAT, YARD & COMPANY
1917

Published October, 1917

PREFACE

The original draft of this volume was written for the use of a small corps of men who were sent abroad by our Government at a certain stage in the war's development, to study aircraft production and its problems, most of these men coming from the motor car plants of Detroit.

At that time occupying the position of Chief Engineer of the Aircraft Division for the Packard Car Company, Mr. W. B. Stout was approached by some of the men who were being sent, and who asked for information that would help them in their work. Mr. Stout presented a copy in typewritten form with blue-print illustrations to each of those going from Detroit. The de-

mand for copies which has continued to this day has resulted in a redraft of the book with more complete material and illustrations, so that it may be available as a helpful guide to the great body of American men who are taking up the study of aviation.

THE PUBLISHERS.

CONTENTS

CONTENTS

THE ILLUSTRATIONS

ACQUIRING WINGS

ACQUIRING WINGS

NOTHING could be simpler than the theory of the modern airplane.

An airplane is nothing more than a large kite, the thrust of the propeller taking the place of the pull of the kite string. An airplane is supported in the air however, by its motion through the air rather than by the motion of the wind past the machine stationary.

The basic principles of the flying machine can be learned from an ordinary blotter, as shown in Sheet 1.

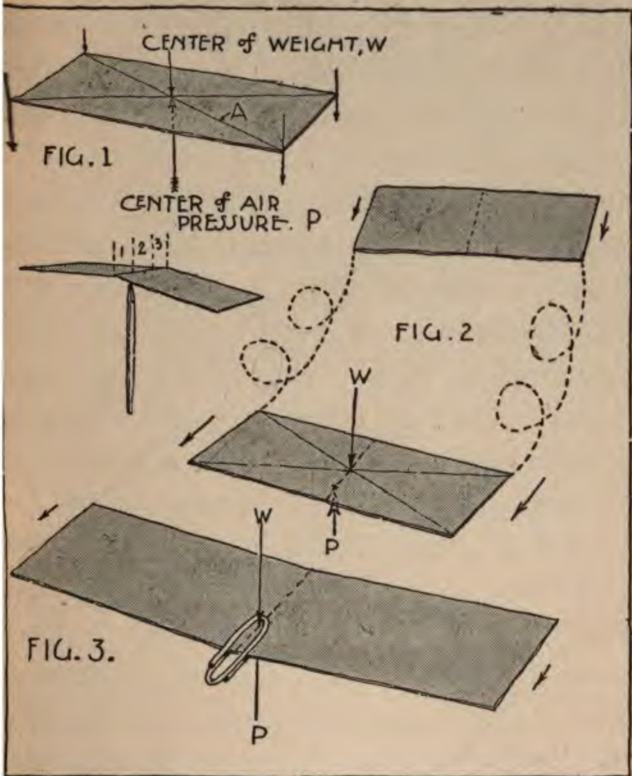
Learning from a Blotter.

In Fig. 1 is shown a blotter with lines drawn crosswise from the corners. These

intersect at the center of the blotter. This point is also the center of weight, as may be proved by balancing the blotter on the point of a pencil at this point.

If the blotter is held in the air horizontally, and dropped as indicated by the arrows at the corner of the blotter, the blotter will fall straight down without upsetting. This is because the wind pressure, coming up from beneath as the blotter falls, has its center at the same point as the center of weight of the blotter, as shown by the arrow P.

Fig. 2 shows an entirely different condition, when the blotter is dropped with a forward motion. The center of weight of the blotter is of course at the same point it was before; but as the blotter moves forward through the air, the air presses harder toward the front edge of the blotter than at the rear, so that the center of air pressure



SHEET 1.—The first principles of flight, as they may be learned by experiment with an ordinary blotter.

moves forward toward the leading edge. Since the weight center W is pushing down, and the wind pressure P is pressing up and forward of the weight center, the blotter will spin, as shown by the dotted lines in Fig. 2. Thus, the blotter in this form will not fly because the center of wind pressure does not coincide with the center of weight.

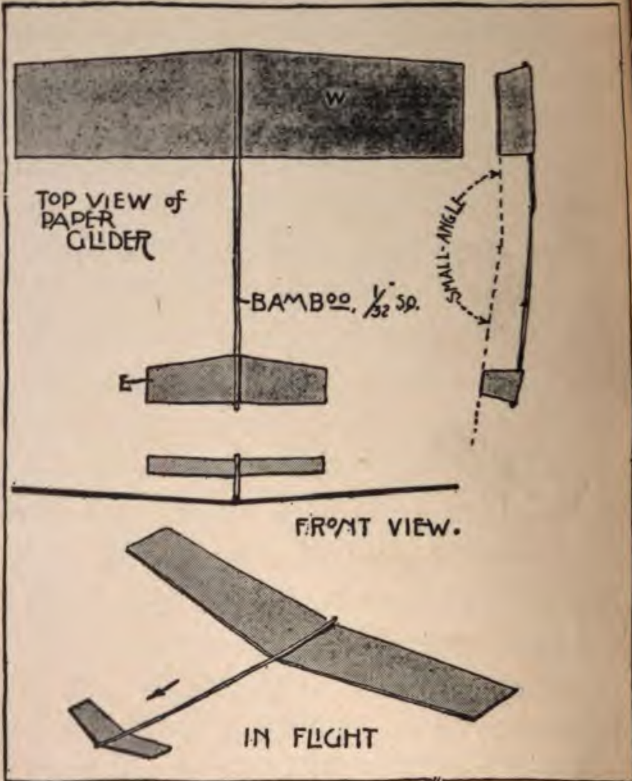
Fig. 3 shows how by means of a couple of paper clips or some other handy weight, the center of weight of the blotter can be brought forward so that it will balance at a point about one-third of the distance back from the leading edge, as in the sketch beneath. We have now made the center of weight coincide with the center of wind pressure, and if we drop the blotter, with the weighted edge in front,—and with the blotter creased a little as shown by the dotted line to give it a slight stabilizing "dihedral" angle instead

of whirling over,—it will take a direct line of flight, and if not too heavily weighted, fly clear across the room.

Thus, we have made a very inefficient toy glider; but have discovered from it that the secret of flight is to get the center of pressure at the center of gravity, or, as an engineer would state, to get the C. P. at the C. G.

A Toy for Practice.

In the blotter glider, we took the most inefficient way of getting flight by adding useless weight to the machine. A better way would be instead of making the center of gravity come forward to meet the center of pressure, to add more supporting surface at the rear to make the center of pressure go back to the center of weight. This can be done by gluing a little strip of bamboo in



SHEET 1*a*.—How to construct a small paper model so that one may learn flying principles by actual experience and at no expense.

the V of a bent paper wing, this bamboo being about two-thirds as long as the wing. At the outer end of this stick, a small wing surface is added as a balancing plane. A model so made is shown in Sheet 1*a*. The surface of the front plane can be very small compared to the big one, and yet do its work. By using a small sliver of bamboo, little gliders of this type only a few inches long can be made with ordinary writing paper, and which will give successful short flights. These small models fly tail first much more successfully than with the large surface leading, on account of the difficulty of obtaining rudder action.

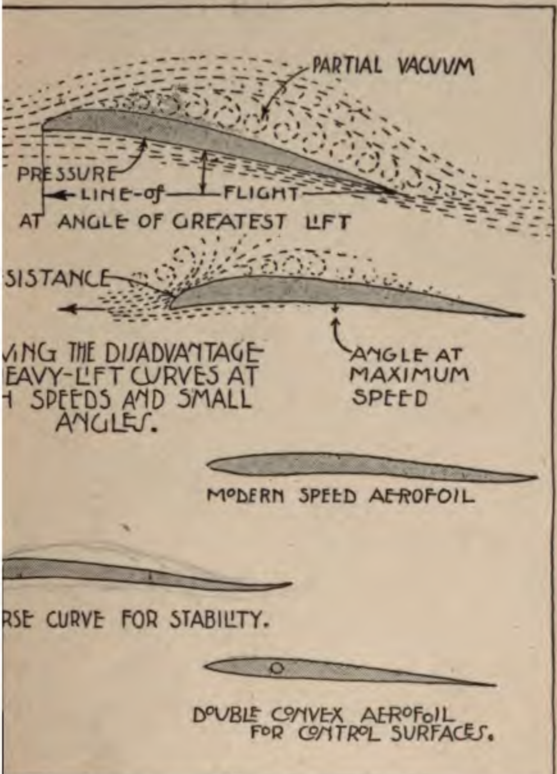
An airplane only differs from a glider in that it substitutes motor power for gravity, and if you imagine the glider of Fig. 3 with a small engine in the place of the paper clip, turning a propeller to draw the glider

through the air at the speed at which it would fall as a glider,—or in other words at its sustaining speed,—you will have the whole idea of what an airplane is.

(Incidentally, the word "aeroplane" is no longer used, the word "airplane" being the correct one. The word "seaplane" also takes the place of the former cumbersome "hydro-aeroplane.")

Wing Theories.

Sheet 2 shows the general theory of an airplane wing. The upper drawing shows a weight-lifting wing of somewhat usual deep section, moving forward in the line of the arrow along the "line of flight," as marked. Dotted lines show the action of the air currents, and you can see at once that the greatest air disturbance is above the wing rather than below it. Ordinarily, the deepest curve in a wing comes about one-third of the way back from the leading edge, and this point is generally pretty close to the center



2.—Showing how a wing creates support, and the dvantage of deeply curved wings at high speeds.

of pressure of that wing. Following the dotted lines beneath the wing, one can see how the air striking the lower surface of the wing is gradually diverged downward. At this point, the air is under pressure, pushing up against the under surface of the wing. Over the upper surface, however, the opposite action is taking place, and the air stream acting over the front edge creates a negative pressure or partial vacuum above the upper wing surface, and it is this very largely, which gives a plane its lift. The dotted lines show the eddies in the current which represent the partial vacuum area.

It will be seen that the higher speed the plane is put to, the greater will be the pressure below the wing and also the vacuum above, so that after the vertical pressure on the wing equals the weight of the machine, any further pressure on account of higher

speed would tend to flatten out the angle at which the wing is flying, making it take on a more horizontal flight, until at high speed the wing has an attitude something like that shown in the second view, Sheet 2. Here there is a tremendous resistance and loss building up at the front edge of the wing on the upper side, and any increase in speed by adding horsepower to the plane will merely bank up more air in front of the wing at this point, and create greater instability, so that we see at once that the shape of a wing, rather than the horsepower of a plane, is the great determining factor in airplane speed.

Wing Range.

For heavy lifting at steep angles of attack, a deeply curved wing, as shown, is an advantage, but when speed is desired, a wing of this deep curvature is of small use.

High speed wing curves must be flatter and have less resistance at small angles. On the other hand, these speed curves lack lifting power at steep angles, and hence lack slow speed performance.

A little study of how these wing curves act will show you why airplanes to-day must be designed for specific uses.

With a fixed wing curve, if one designs for high speed, he must sacrifice great lift per square foot, and if he designs for extreme lift, he must sacrifice high speed.

On the other hand, if one designs a machine to fly at high speeds it cannot land at slow speeds, and if one designs for the safety of slow speed landing and getting off the ground, you will have a plane which is not capable of extremely high speed. This was especially true in the early stages of airplane development. The early Wright machine, for instance, got off the ground between 35

and 40 miles per hour and flew to a maximum of 50, having practically no speed range. Wonder was that they flew at all, although to-day it is doubtful if there is any machine more efficient from a strictly mechanical sense and for small horsepower than was the Wright layout.

The danger of small speed range was soon found out, for when flying in machines of small speed range, a gust of wind might strike the machine from the rear while it was flying and if this wind-gust was of greater speed increase than the flying range of the plane, then the aviator was in what was called an "air pocket," for all support temporarily would be taken out from under the wings, and the pilot would have to drop for some distance, acquiring forward speed before he got to going fast enough to support himself again.

It is rare that a wind gust appears with

over a 20 miles an hour increase in air speed, so that if any plane to-day has a speed range of 20 miles per hour—say from 40 to 60 or 50 to 80—this plane is practically free from the effect of this type of "air pocket."

The chief aim of designers to-day then, is to accomplish speed range so that a machine can get off the ground and land at the safest possible speeds, and yet accomplish in the air maximum speed also.

By using a wing curve of low lift per square foot and increasing the wing spread to take care of the total weight to be carried, rumors are afloat that the allies have produced a machine with a speed range of from 50 to 150 miles per hour.

Eventually, by the use of a wing curve which is variable in the air, we will be able to have heavy lift curves for getting off the ground and landing and to flatten out these

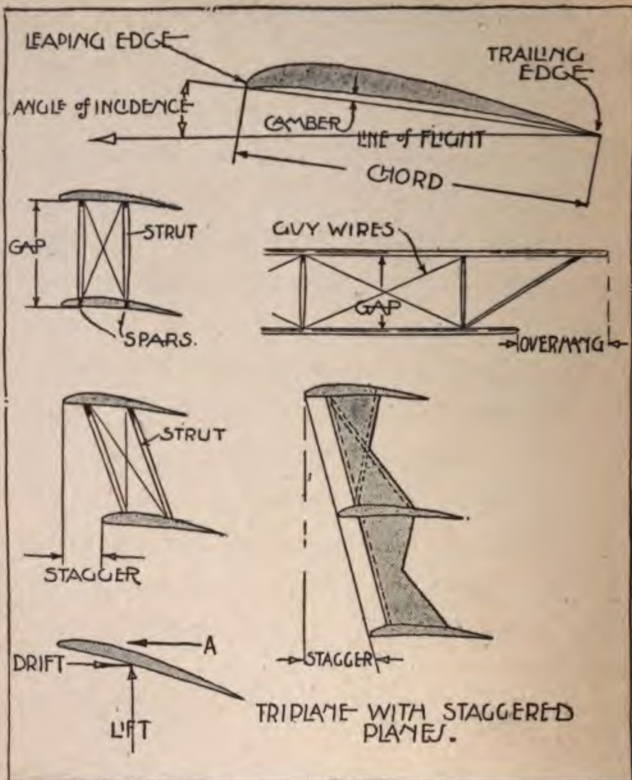
curves for speed work after we get in the air.

When some one invents a variable-camber wing which will be infallible in its working and of absolute simplicity for safety, the airplane will immediately enter a new field of activity.

Other views of Sheet 2 show different wing curves, a modern speed aerofoil, a heavier lift reverse curve, which gives a large degree of horizontal stability by its own shape, and a new double-convex aerofoil which has been used for control surfaces, but which offers promise for excessively high speed airplanes.

Wing Terms.

Having discussed the wing curves or "aerofoils," as they have come to be designated, as to their theory, the nomenclature of their construction will not come amiss at



Sheet 3.—Names relating to wing curves and wing arrangements, with a diagram explaining lift and drift.

this time, and at the top of Sheet 3 is shown a section of a wing. The "leading edge" and "trailing edge" explain themselves. The "angle of incidence" at which the plane is flying is ordinarily considered to be the angle between the "line of flight," or the direction in which the plane is flying, and the "chord" line of the plane, which is a straight line drawn fore-and-aft tangent to the front and rear edges of the aerofoil.

The "camber" of the plane is the depth of its curve, as measured from this chord line. In the lower left hand corner of Sheet 3 are shown the terms used in connection with the plane's action.

Lift-to-Drift.

When a wing is traveling forward through the air as in the direction of the arrow A, there is a certain resistance to its forward

travel, this resistance being known as "drift." In overcoming this amount of resistance or drift, a certain lift is given by the wing, an upward component of the air current from the front striking the wing curve, and being deflected up and down as explained previously.

The ratio of the lift to the drift determines largely the value of a wing curve, and ordinarily that curve which gives the greatest amount of lift with the least resistance to forward travel at the speed for which the plane is designed, is the most efficient "aerofoil," or wing curve.

Wing curves at different angles and of different shape give a lift-to-drift ratio varying from approximately 1 to 1 on a flat plate to 8 or 10 to 1 and over, in special aerofoils at unusual angles. A lift-to-drift ratio of 8 to 1 is easily accomplished. This means

that for every pound of forward thrust given by the propeller, 8 pounds of weight can be lifted vertically at the normal speed of the plane.

A detailed discussion of lift-to-drift and its relation to airplane design I will leave for more technical discussions.

In a biplane or any combination of superimposed planes, the vertical distance between one plane and its nearest neighbor is known as the "gap," while the sticks which separate the planes are known as "struts." If the upper plane projects forward over the lower plane, or vice versa, the distance of the projection is known as "stagger," as shown in the drawing. If the top is built longer than the lower plane so that it projects over the lower plane on each end of the wing, the distance of this projection is known as "overhang," as shown also in the

front view, Sheet 3. Below it, is shown a triplane wing arrangement, the struts in this case being of peculiar construction and enclosed in fabric to eliminate wind resistance or "head resistance."

Head Resistance.

This item of head resistance is of tremendous importance. There is a difference between the resistance to forward flight which a wing curve shows as part of its lifting function, and the head resistance of other non-lifting parts, such as body, struts, engine, tail-surfaces, etc., these being known as "parasite resistances." Colloquially, it is usual to speak of head resistance as something separate from drift, and yet the head resistance of a plane means the combination of both the resisting "drift" of the wing sur-

face and the "parasite resistance" of the non-lifting parts.

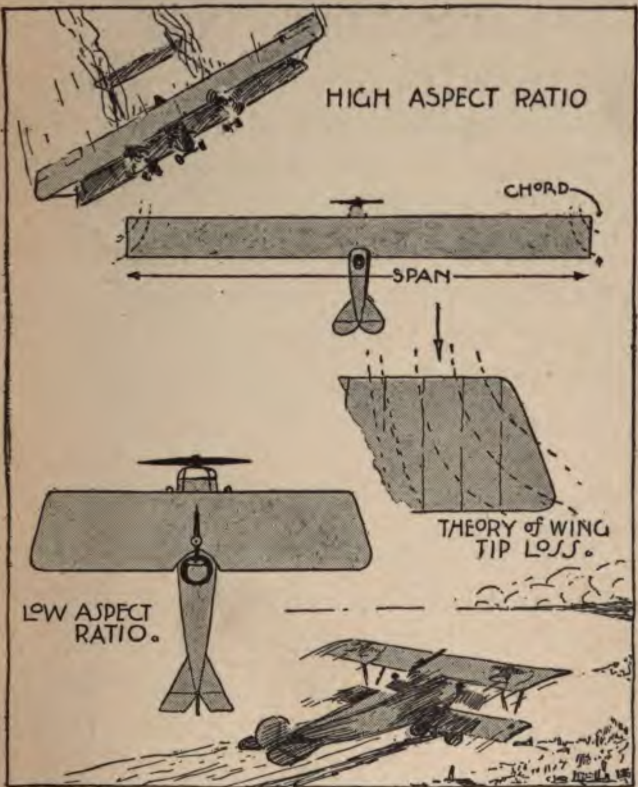
The surface which these parasite parts offer to the air which they are fighting must be as small as possible, and streamlined down to the last wire, if real speed is to be obtained. Streamline shape can best be visualized by thinking of a fish—which is of real streamline form,—or of a bird's body, or of an egg drawn out to a point on one end, or of a cigar, thickest at a point about one-third the way back from one end.

Streamline shape is that shape which can travel through the air and leave the least vacuum or air disturbance behind as a wake.

Value of Streamlining.

To move a square foot of flat surface directly against the air at 100 miles per hour,

takes a pressure of close to 20 pounds. An ordinary airplane engine driven through the air at 80 miles per hour consumes about 50 pounds of thrust. Since the ratio of lift-to-drift on a well curved wing may be around 16 to 1 at speed, for every one pound of resistance to forward travel which we put in the machine, we take away the ability to lift 16 pounds, so that for the 50 pounds resistance of our airplane engine out in the air, we are losing 16 times this much, or 800 pounds in lift, or possible weight carried at maximum speed. By enclosing the engine and eliminating even half of the air resistance of forward travel which the motor gave before, we can add 400 pounds, or the weight of two passengers to the machine without interference with performance. These figures are rough, and are changing with every improvement of plane and wing section, but



Sheet 4.—Planes in plan and in action, explaining "aspect ratio" and the theory of wing tip loss.

they illustrate the excessive and growing importance of eliminating wind resistance in airplanes, and of enclosing every part possible within streamlined cases.

As has been stated, the total width of the plane from front to rear is known as the "chord." The length from tip to tip of the wing is known as the "spread," as shown in Sheet 4.

Aspect Ratio.

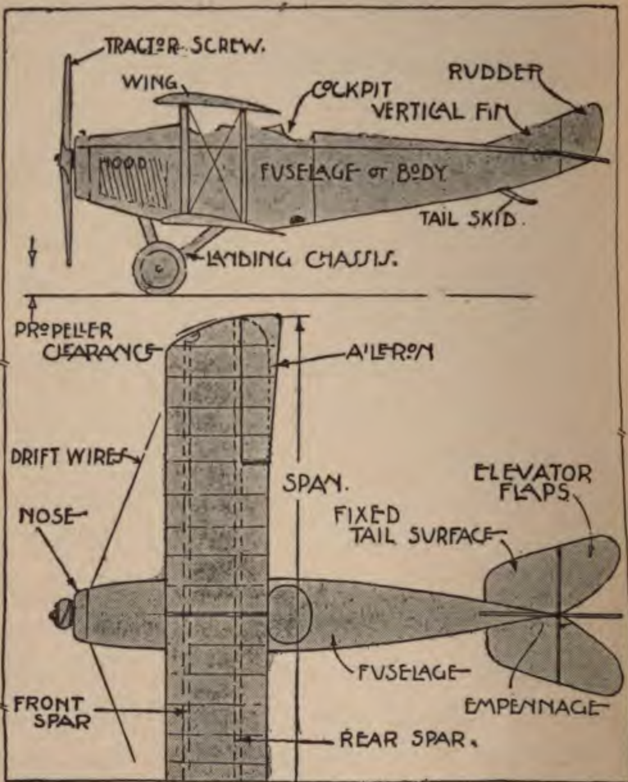
The "spread" divided by the "chord" gives what is known as the "aspect ratio."

If a wing is six times as long as it is deep, having a spread equal to six times the chord, it has an aspect ratio of six, which is about average for training biplanes. Anything much above this would be called to-day a high aspect ratio, whereas a plane with

wings three times as long as they are deep, would be said to have a low aspect ratio.

Large, slow-speed machines such as bombers and battleplanes ordinarily have a high aspect ratio, whereas speed scouts usually are built with a low aspect ratio.

Theoretically, the wing with the highest aspect ratio is most efficient, as there is less loss at the wing tip. Sheet 4 shows the theory of wing tip loss by dotted lines, showing how the air entering the front edge of the wing near the tip slips out sideways toward the end and is lost before it has really done its work. By having a higher aspect ratio, there is less length of wing tip end to offer space for this spillage. It has been found, however, that above six to one, but small benefit is gained by increasing aspect ratio.



SHEET 5.—Nomenclature of the more common elements of airplanes, shown in both elevation and plan view.

Nomenclature.

Sheet 5 gives the most common names of parts of the modern airplane.

First there is the "fuselage," or body. This is generally constructed of square sticks in box girder form, trussed with piano wire and covered with airplane fabric. At one end,—the front in the tractor type shown,—are carried the engine and propeller; while at the opposite end, is the tail assembly of rudder, rudder fin, fixed tail surface, or horizontal stabilizing fins, elevators and rudder, this assembly being termed the "empennage."

Passenger Location.

The passenger and pilot stow themselves away in "cockpits," the pilot often in front at the center of pressure of the plane, in war work, and the observer at the rear where he

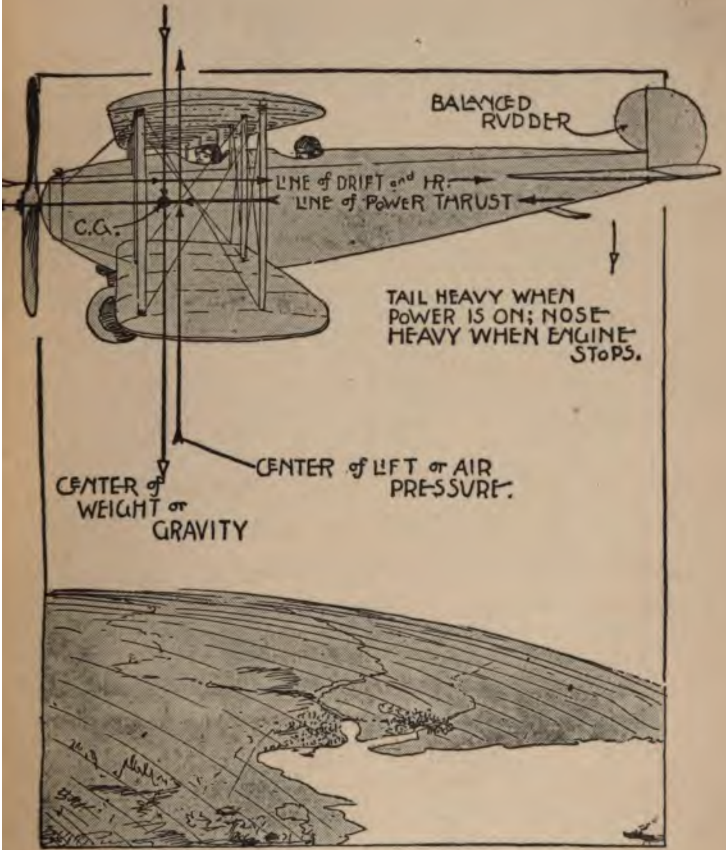
can get greater range of action with the machine gun. The ideal, from the designer's standpoint, is to have the pilot at the rear cockpit and carry the passenger or observer at the center of pressure,—which of course is the center of weight,—so that the plane will balance equally well whether passenger is aboard or not.

Tanks.

The gas tanks also are located on the line of the center of pressure, so that the plane may balance the same whether the gasoline tanks are full or empty. Ordinarily, the tanks are swung rather low and fed by the pressure or vacuum system to a small tank under the upper plane, from which tank a pipe carries the fuel to the carburetor.

Nomenclature of Plane.

In the upper view of Sheet 5 showing an



SHEET 6.—Explaining the principles of balance as applied to the entire plane in the air. Especially note the positions where the various action and reaction lines cross.

ordinary tractor type of airplane, the principal parts of the machine are labeled with their correct names. One disadvantage of the tractor type will be noted in the necessity for carrying the fuselage high from the ground with a more or less elevated landing chassis, to keep the "propeller clearance" from tip to ground, a proper and correct distance. The necessity for having the propeller in this location is indicated in Sheet 6, which shows the balancing principles of an airplane.

Plane Balance.

On account of control reasons, the center of weight and the center of air pressure do not exactly coincide in a machine which is large enough to carry a pilot; the center of weight being carried a trifle forward of the center of lift, tending to make the machine

nose-heavy so that if left alone, it would dive sufficiently to glide automatically at its rated speed.

The line of "power thrust" or propeller pull, however, is located below the line of "drift and head resistance," so that the pull of the propeller tends to make the machine nose up, pulling the tail down. Thus, the machine flies tail heavy when the power is on, but becomes nose heavy the minute the engine is stopped. This indicates the accuracy with which a propeller must be placed to produce a properly balanced machine.

Plane Arrangements.

Airplane types are generally one of three constructions; monoplane,—biplane (with two wings, one above the other and by far the most common type)—and multiplanes,

—the Curtiss and Sopwith triplanes being examples of the latter.

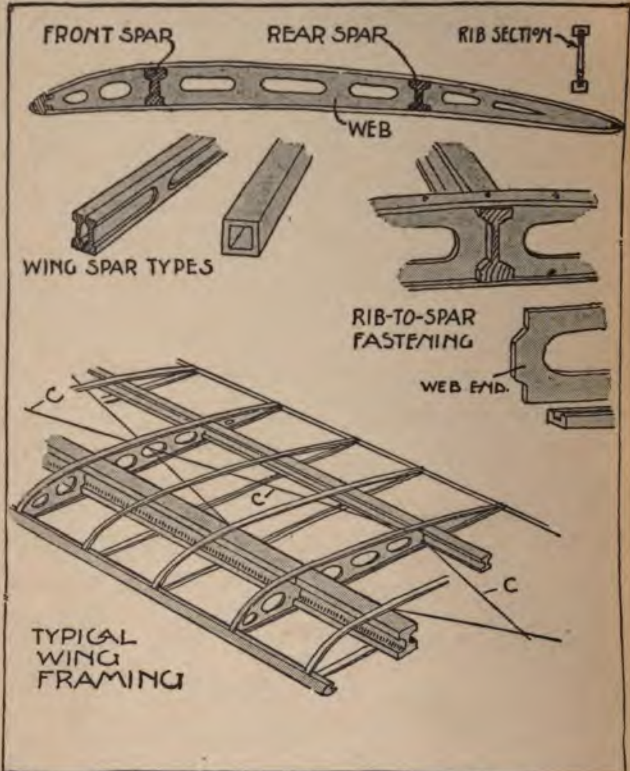
A large number of guy wires are necessary on the monoplane, these bracing from the chassis under the wings and to a central "cabane" or tripod above the wings. The necessity for this number of wires and the amount of head resistance which they create is one reason for the small use of monoplanes in warfare.

Wing Construction.

By now, you may have become curious regarding how wings are made, so in Sheet 7 I have shown diagrammatically, how a wing is ordinarily constructed. The view at the top shows a wing curve and a side view of a main wing rib. In the first place, are the wing spars, front and rear, located never twice in the same place, but seeming to vary

with the whim of each individual designer, although he is limited in the strength of the wing spar by the curve which he chooses for his plane. On either side of these spars run thin strips of spruce, bent to form the proper wing curve on top and bottom. The main ribs are separated and held in shape by thin webbing between the outer ribs, this being cut full of holes as shown, for lightness. This gives the wing an I-beam section of great strength for its weight. A certain number of ribs between the main ribs are constructed without support other than the spars, on narrow chord sections, and by spacers or extra wing spars on wide chord wings. The leading edge may be a U shaped spar of wood, metal or veneer, while the rear or trailing edge is generally wire or small steel tubing.

To take the strain of the head resistance



SHEET 7.—Explaining conventional wing construction, with details of various parts contained in the assembly.

cross wires "C" are in tension between the front and rear spars. Those wires of this internal bracing which take the resistance to forward motion of the wind through the air are called "drift wires." The wires crossing them in the opposite direction are merely reënforcements to hold the wing as a rigid construction, and are sometimes called "landing wires."

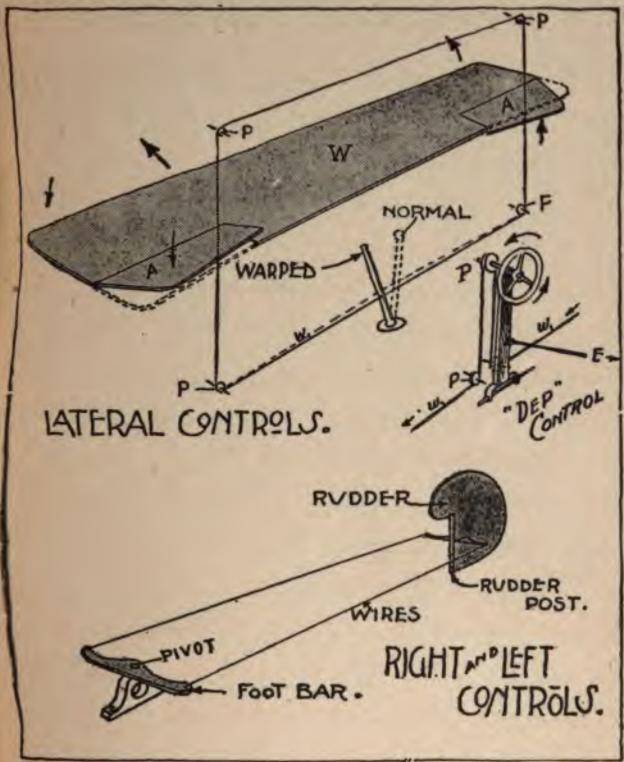
The drawing on Sheet 7 at the center on the right shows how the web is made to fit snugly against the wing spar, to hold the entire wing in assembly with maximum strength. Similar sketches show types of wing spars, of hollow, I-beam, or double I-beam section.

Controls.

Many modern planes are made automatically stable, so that one may take his

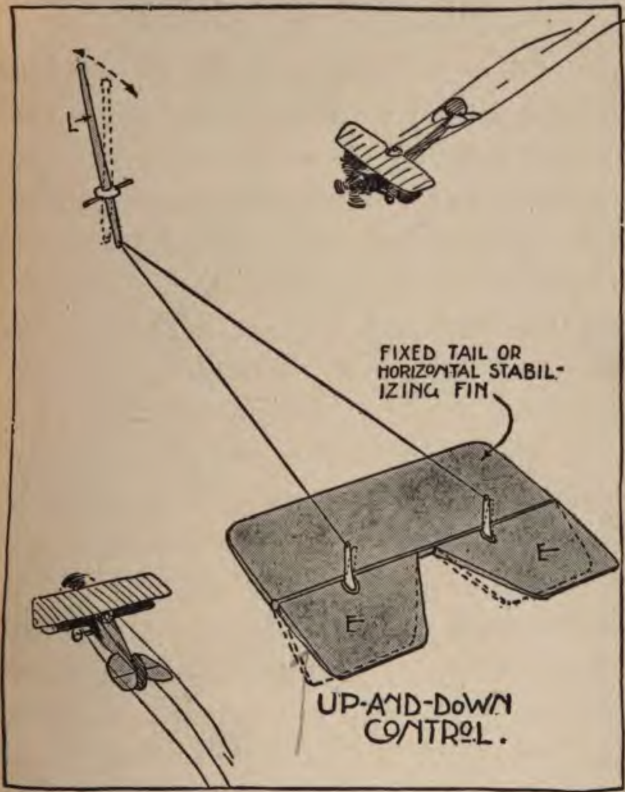
hands off the controls for long continued periods or may even take a tail slide or side slip with his hands off, and have the machine right itself and take a natural gliding angle automatically. There are disadvantages, however, to a stable machine so that many fliers prefer the very controllable but unstable type, especially for very high speed work. An airplane is controlled in two ways, or rather by two types of lever arrangement. The first is known as the Dep control (abbreviation for Deperdussin), with a wheel like the steering wheel of an automobile, as the means of working the aileron, as shown in the small upper sketch on Sheet 8. The more logical and preferred type for speed work, is the stick control shown in the rest of the sketches on Sheets 8 and 9.

First, to explain the action of the aileron



SHEET 8.—Showing how the ailerons are worked by the control lever to keep the machine on a normal keel, together with diagram of foot control for rudder.

in the upper drawing, Sheet 8. Suppose the wings to be traveling forward at high speeds and for some reason or other the wing to your right starts to drop and the wing on your left to rise. In other words, the plane starts to upset to the right. By pushing the lever or "joy stick" toward the side you want to push down, with the natural motion you would take subconsciously to lift the wing that was falling, you pull down the flap or aileron on the low side, and raise that on the high side, all of this being shown by solid lines. This means that the right hand aileron has an air pressure underneath it lifting that wing, while the left aileron has a pressure on top tending to push it down, so that the wing and the entire machine by the action of the aileron, is pulled back to a horizontal flight. Then the pilot brings the joy stick again to the vertical position as



SHEET 9.—How the control lever works the elevators to steer up and down. Though shown with stick control, the principle is the same with the "Dep" control.

shown by the dotted line and the ailerons again trail out neutrally behind the wing. Thus, by moving the stick from side to side as you sit in the pilot's seat, the ailerons are worked up and down and lateral balance is obtained. In the Dep control, the turning of the wheel works the aileron, but the stick does not move from side to side.

Moving the stick fore and aft works the elevators at the rear of the machine, as shown in Sheet 9. The fixed tail surfaces of the empennage are sufficient to hold the machine in normal flight, at its normal flying angle. If the joy stick is pulled back, the elevators are raised to steer the machine up, and if it is pushed forward, the elevators are dropped, giving an upward pressure on the tail surfaces, steering the machine down. In this action, the fixed tail surface tends to damp

out oscillations or bouncing of the plane and hold it at its normal flying angle.

Steering.

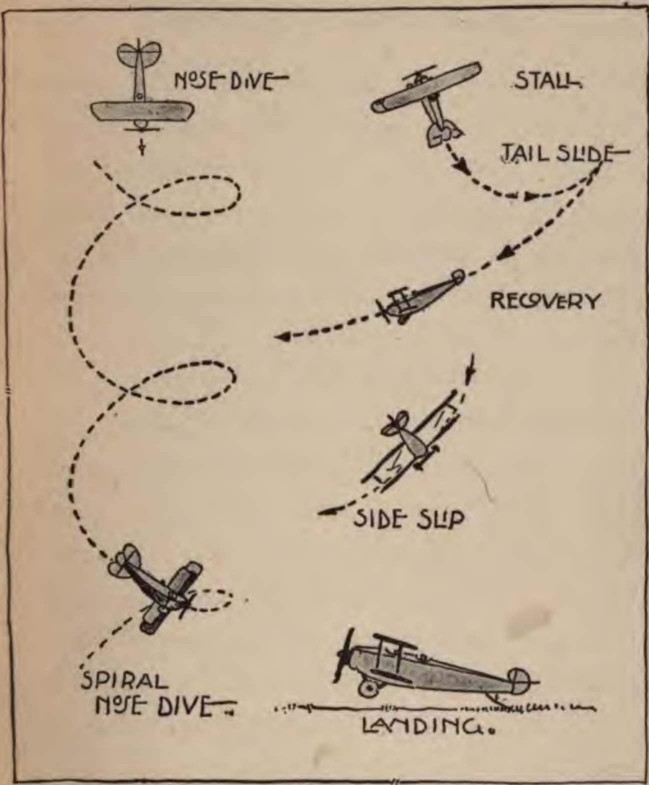
Steering right and left is accomplished by the rudder on a hinge vertical and ordinarily at the rear end of the fuselage. The rudder is connected to a foot bar in front of the pilot, so that all steering right and left with the rudder is done by means of foot action. In practice, the control is through a number of operations to get proper banking before starting to turn, so that the machine will not skid or side-slip, the amount of banking necessary being learned by experience in the air.

In Sheet 8, the wires running from the control pillar to the ailerons in both types of control are marked "W." In the Dep control these wires run around pulleys "P"

at the base of the steering column, up and around another pulley "P" on the shaft of the steering wheel, so that, when this wheel is turned, the wire "W" is turned one way or the other, to operate the ailerons. This type of control is used extensively on large machines.

Flying Terms.

There are a number of terms used in connection with flying which are shown diagrammatically in Sheet 10. A nose-dive occurs when a descent is made at too great a speed or too steep an angle, so that the pressure of the air gets on top of the leading edge of the wing which is not designed for so high a speed, as in Sheet 2, and it takes considerable rudder action to pull the machine out to horizontal flight again. In early machines it often happened that pilots failed



SHEET 10.—Explaining terms used concerning flying, and the more or less unusual positions which the modern pilot may assume as part of his day's work.

to recover from a nose-dive and many were killed before the reason was understood and a remedy found.

In trying to climb at too steep an angle, new pilots sometimes allow their machines to slow down below their supporting speed, when they stall and drop tail first. This used to be a very dangerous happening, but if sufficiently high in the air, modern stable type machines will recover themselves, as shown by the dotted lines.

Side slip is caused generally by taking a turn with insufficient banking, which causes the wings to lose their sustaining effort once forward motion is stopped. Fliers who know how, however, can now side slip for hundreds of feet and right themselves in safety. This was one of Boelke's favorite tricks.

In landing, the pilot ordinarily flies par-

allel to the ground with his motor shut off, dropping the tail of the machine until the skid touches, when he switches on his engine with the elevator up, which jabs the tail skid into the ground further, bringing the machine to a quick stop, the wheels touching the ground last.

Military Types.

Types of machines used abroad in war work are somewhat as follows:

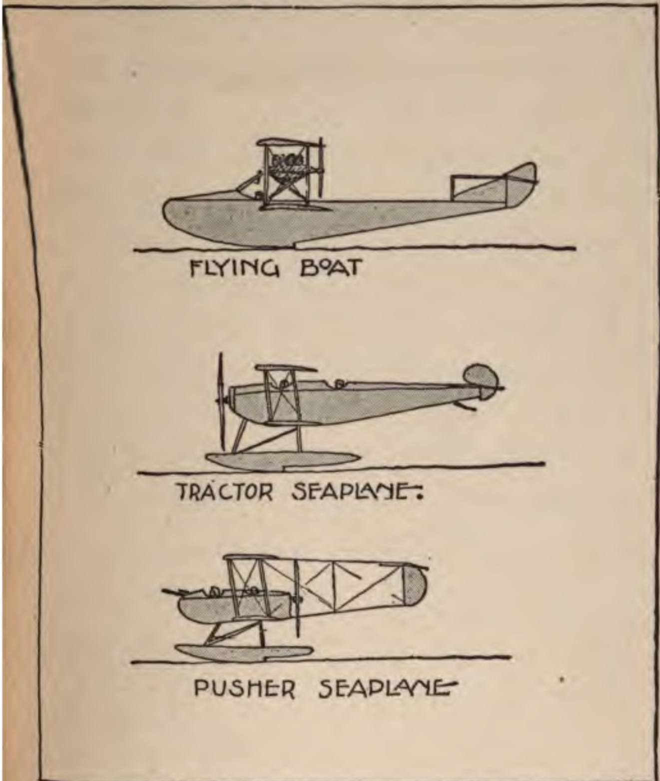
Speed Scouts,—Speed up to 150 miles per hour, climb up to 10,000 feet in 10 minutes. Carry pilot only and fuel for not over 3 hours. Machine guns shooting forward through propeller, and to rear.

Tactical Reconnoissance,—Two-man machines, both pilot and observer operating machine guns, speed up to 120 miles per hour.

Battleplanes or Bombers,—These are high-powered machines of great wing spread and often fitted with two motors or more. These carry loads of over a ton with a crew of several men. Ordinarily, they are not fast—say around 90 miles per hour at a maximum,—and in attacking work are protected by a mosquito fleet of scouts, both above, below and behind them. They have a wide range of action, and are fitted almost invariably with twelve-cylinder engines.

Airplane Engines.

In visualizing an airplane engine to yourselves, who already know about automobile and marine prime movers, one needs mainly to understand the different type of service which the airplane engine must perform as compared to automobile and marine work. The fundamental differences are that the airplane engine



SHEET 11.—Three prominent types of water machines: the flying boat, the "tractor" and the "pusher" seaplane.

1. Must work for extreme periods under wide open throttle.
2. It must operate at high altitudes.
3. It must be of absolute minimum weight.
4. It must be of maximum reliability.
5. It must be of large horsepower per engine unit.

The nearest example we have in previous gas engine practice to the airplane engine is the automobile racing power unit. These engines were built to run at maximum load for long periods of time, and yet, under road conditions there was a continual letting up on the throttle, which enabled oiling systems to act with far more efficiency than where the throttle is left open all the time. These engines also operated at or near sea level conditions.

Power.

The modern airplane engine is not required to run at wide-open throttle position on the ground except for a short period of time, sufficient to allow the machine to which it is fitted to climb to a 5,000 to 10,000 foot altitude. At 6,000 feet, the density of the air has so decreased that with wide-open throttle the engine is producing but 90 per cent. of the power it gave on the ground.

Life.

An airplane engine, therefore, should be able to run for an unlimited time—within the limits of mechanical possibilities—at 90 per cent. of its power. If the engine be designed for work at 10,000 or 15,000 feet, then it can be still further lightened, for at this altitude, it may be running at 40 or 60 per cent. of its power on the ground, and

need, therefore, have bearings which will stand only this load.

The future development of airplane engines will be fast and will include types for many different services, although the average engine probably will do most of its work at around a mile height.

Types of Construction.

Two types of water-cooled airplane engine constructions in large horsepowers have so far proved especially successful, those having aluminum cylinders with steel or cast iron liners, and those with steel cylinders with welded steel jackets. The latter have many advantages of lightness, and easy replacement in field service, and hence at the present time are dominant in the field.

Cost in Man-Hours.

In designing an airplane engine for war

use, the engineering of the engine itself to give performance is not the entire story. In ordinary manufacture, cost is the main item in producing any new product, and one would think that for government and war work, one could forget the item of cost. Cost, however, represents man-hours of effort and during war periods, man-hours are deemed more valuable than at any other time, so that an engine must be laid out for quick production with the least amount of labor, not only to save the man-hours, but that time may be saved,—and time in the war is a tremendously valuable asset.

Simplicity of production also means simplicity of repairs and accessibility, and this brings us to the second necessity for war work, which is service and replacement.

Service.

Parts on all sizes of motors must be as nearly standardized as possible, so that from two broken engines, a new serviceable engine may be built up right on the field, and without workshop equipment in case of necessity. One of the most promising engines abroad, so far as its performance was concerned, in the early part of the war, was hindered from acceptance by the foreign War Departments through the fact that no two cylinders of the twelve with which it was fitted were interchangeable, so that twelve cylinders had to be carried along in the field by the Service Department for each single engine, this requiring too great a transport unit in proportion to the size of the plane equipment.

The Germans have realized from the start the necessity of standardizing on few types

of motors and producing these in quantities, as nearly similar as possible. This has largely been the reason for their ability to hold even with the Allies in air work, not only because of their concentration on production, but that they have continued to develop the same type to a higher stage of efficiency.

Future.

Lord Northcliff has stated that what the Allies need from America is men and ideas. It is going to take us considerable time to get men in quantities to the European battlefield in condition to be of assistance. Our ideas should be ready and in operation by the time these men leave. Lord Northcliff also has from the beginning been a tremendous factor and influence in the development of the airplane for war, and has

emphasized time and again the importance of America's production of many planes and engines for war work.

Europe during the war has taken the old types of planes and has developed from them the present type of machine. We may look in the near future for machines of new types, and there is vast opportunity in America for those who have ideas to carry to the limit the development which will bring out new performances.

Wing shapes are fairly well understood, and comparatively little can be expected from development in this quarter. One can expect, however, a great deal from the perfection of a variable wing curve type of machine. This is not a problem of aerodynamics, but of mechanical arrangement and construction, and choice of material very

largely, and is not by any means an unsolvable problem.

It is very likely that the development of the newer planes in other points will be along the lines of new mechanical layouts for gaining greater results of lightness and handiness and less head resistance, rather than any new radical aerodynamic ideas.

It took 20 years to develop the automobile and its allied industries, the development of these allied industries of steel making, heat-treating, quantity production, etc., being necessary for the development of the motor-car industry.

With the coming of the airplane, we have at our command all these developed industries and processes, so that we have very largely only the plane itself to develop.

This, with war incentive, will mean that

the airplane will be perfected in five years to a point equivalent to the commercial perfection of the automobile in twenty. Thus, aircraft engineering will move four times as fast as did automobile engineering, and those involved in the perfection of aircraft will of necessity have to be men of vision and ideas, who can see ahead and can act further in advance than has been necessary in automobile work.

No idea is too insignificant to receive attention from those interested in the development of aircraft, and no proposed design, no matter how radical, should be laughed at by engineers at this stage of development, unless its fundamentals have been proved fallacies. Naturally, there will be millions of foolish ideas proposed which deserve no attention, and yet even these should at least be considered through the possibility of their

containing the germ of a greater idea which some one else might get from their suggestion.

The automobile has brought us a new earth and a new method of thinking. Now aircraft shall bring to us a new heaven and a wider vision, that we who are interested and concerned in the development of the progress of mankind and democracy may come to better things and to greater reaches of activity than ever before has been possible.

THE END